



# Radiological Exposure Devices

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<http://www.jrc.ec.europa.eu>

- **Introduction**
- **Exposure - Effects**
- **Accidents**
- **REDs**
- **Exercises**

## Potential Scenarios

- **Radioactive Exposure Device (RED)**
- **Radiological Dispersal Device (RDD)**
- **Improvised Nuclear Device (IND)**

# **RED**

**Radioactive source out of legal control**

**Potential to expose people to lethal doses of radiation**

**Irradiation, no incorporation if sealed source**

**Dose assessment, medical monitoring**

**Psychological & Economical impact**

# **RDD**

**Detonation of explosive device + radioactive material**

**Injury**

**External contamination**

**Incorporation**

**Psychological & Economical impact**

# **IND**

**National emergency situation**

**Large number of victims**

**Effects: blast, heat, radiation**

**Irradiation, incorporation**

**External exposure: irradiation**

**Internal exposure: incorporation**

**Stochastic effects:**

**Propability of occurence increases with dose, no treshold dose  
e.g. cancer incidence**

**Deterministic effects:**

**Severity of effect increases with dose, treshold dose  
e.g. organ dysfunction, lens opacification, blood changes**

## Deterministic effects

| Dose<br>(whole body irradiation) | Effects  |
|----------------------------------|--|
| < 0.25 Sv                        | No clinically recognizable damage  |
| 0.25 Sv                          | Decrease in white blood cells  |
| 0.5 Sv                           | Increasing destruction of the leukocyte-forming organs<br>(causing decreasing resistance to infection) |
| 1 Sv                             | Marked changes in the blood picture (decrease in the<br>leukocytes and neutrophils)                    |
| 2 Sv                             | Nausea and other symptoms  |
| 5 Sv                             | Damage to the gastrointestinal tract causing bleeding<br>and $\approx 50\%$ death                      |
| 10 Sv                            | Destruction of the neurological system<br>and $\approx 100\%$ death within 24 h                        |

Ref.: K. H. Lieser, Nuclear and Radiochemistry: Fundamentals and Applications. VCH/Wiley 1997.



**Nausea**

**Vomitting**

**Headache**

**Diarrhoea**

**Weakness**

**Changes in blood (reduction in Lymphocytes)**

## 1987, Goiânia, Brasil

**$^{137}\text{Cs}$  teletherapy unit source  
removed by scrap collectors,  
source capsule opened**

**54 persons hospitalized, 4 died**

**112.000 persons monitored**

**Large psychological and  
economical impact**

Source: IAEA, STI/PUB/815, Vienna, 1988



## 1994, Tammiku, Estonia

3 persons entered radioactive waste repository

Removed  $^{137}\text{Cs}$  radiation source

Source stored at home

5 persons with deterministic effects

1 Person died

Source: IAEA, STI/PUB/1053, Vienna, 1998

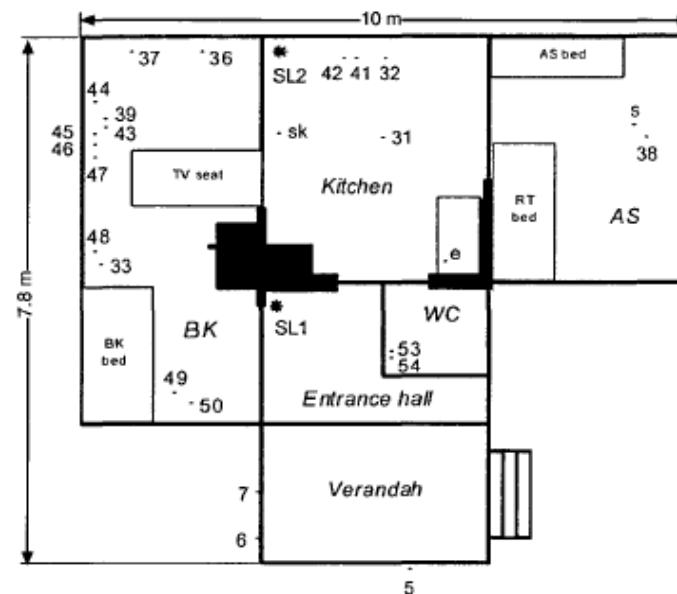


FIG. 3. The plan of the house in Kiisa. Possible source locations (SL1 and SL2) are indicated by the large asterisks. The sample codes are given in Table III.

## 2000, Samut Prakarn, Thailand

$^{60}\text{Co}$  teletherapy unit out of regulatory  
control

Teletherapy head stolen from  
unsecured storage area

Disassembled at junkyard

10 persons with deterministic effects

3 Person died

Source: IAEA, STI/PUB/1124, Vienna, 2002



## **2002, China**

**$^{192}\text{Ir}$  put in office of business rival  
74 persons with irradiation symptoms**

## **1995, Zheleznodorozhny, Russia**

**Criminal act  $^{137}\text{Cs}$  source in door of truck,  
5 months exposure, 1 dead**

**1993, Moscow, Russia**

**Radioactive source in chair of company  
director, 1 death**

**1991, Bratsk, Russia**

**2 similar cases, 1 injury**



**1979, La Hague, France**

**Radioactive graphite fuel element plugs under driver's seat in car, person tried to kill his employer**

**1972, Texas, USA**

**Man used  $^{137}\text{Cs}$  sources to intentionally irradiate his 11 year old son after divorce**

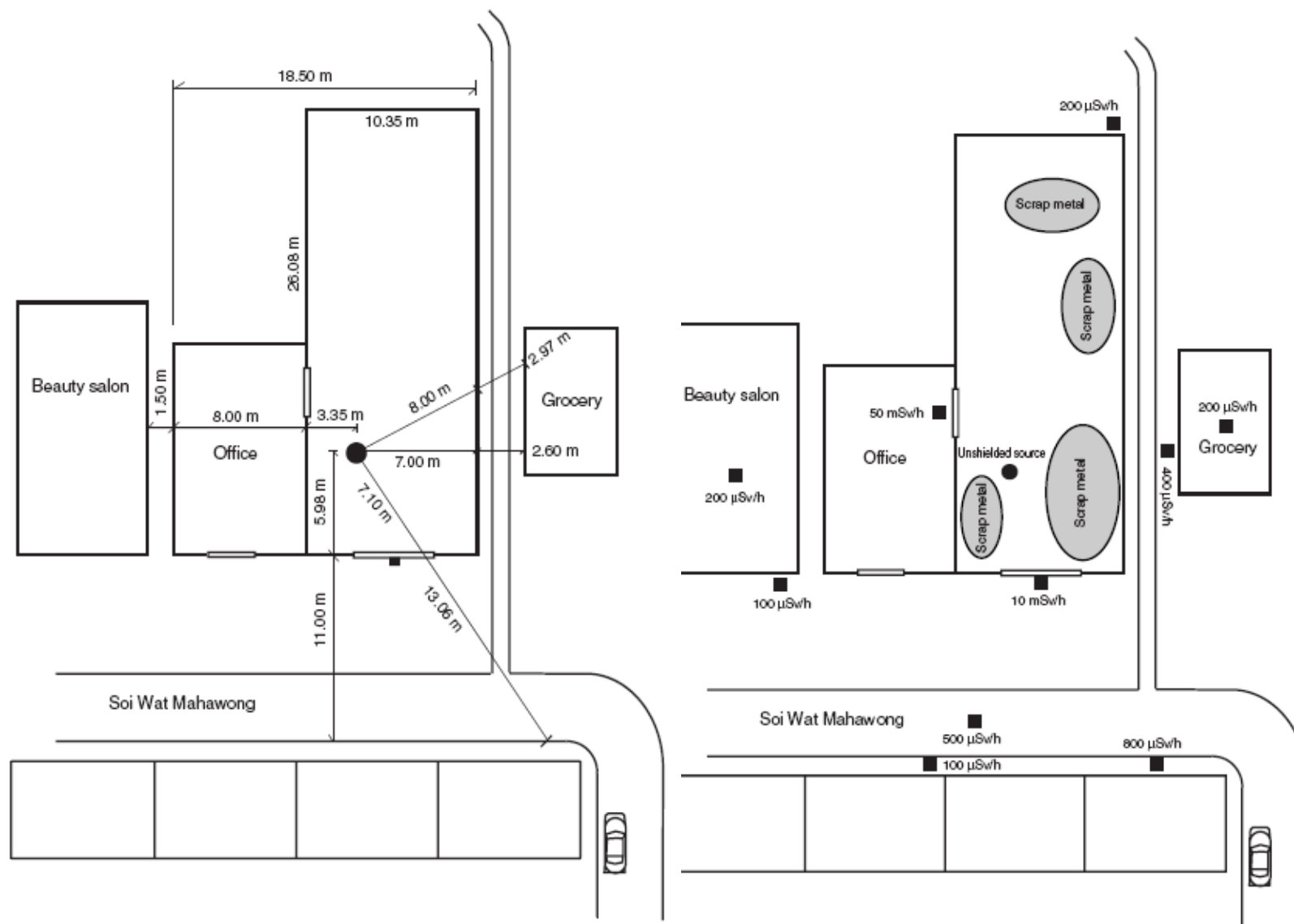
**Source: <http://www.johnstonsarchive.net/nuclear/radevents/index.html>**

## 2000, Samut Prakarn

### Source activity?







**Measured:  $^{60}\text{Co}$ , 10 mSv/h, ~6 m distance**

**Source activity?**

- **Dosimetry & Shielding**
- **Source activity without shielding**
- **Source activity with 10 cm Fe shielding  
(scrap metal)**

Element: Mass:

Co 60  Nuclide Mixtures Selector

Dosimetry and Shielding

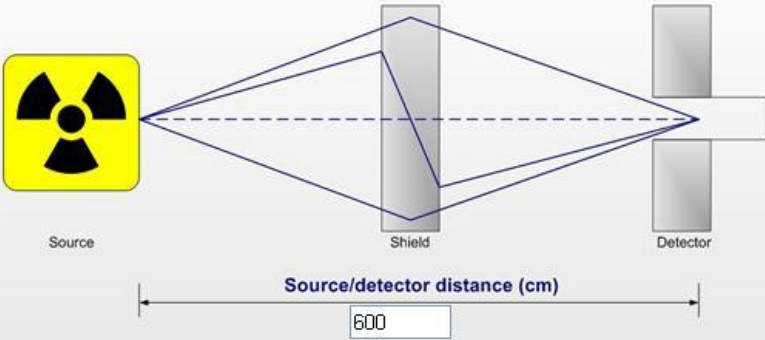
Dose rate/Thickness graph

Options

**Source strength** Activity(Bq)

**Shielding material** Air  cm

**Dose rate (μSv/h)**



Source/detector distance (cm)

Start

Reset

|  |          |
|--|----------|
| Half-Value Shield Thickness(cm)                                    | 2.77E+04 |
| Tenth-Value Shield Thickness(cm)                                   | 6.50E+04 |
| Equivalent Dose Rate Constant $\Gamma$ (mSv·m <sup>2</sup> /GBq/h) | 3.37E-01 |
| Gamma Dose Rate (μSv/h)  | 9.31E+03 |
| Effective Build-up factor  | 1.04E+00 |
| Effective Number of Mean Free Paths (μ·d)                          | 3.96E-02 |

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## Equivalent Dose Rate Constant $\Gamma$

$$\Gamma(\text{mSv}\cdot\text{m}^2/\text{GBq}/\text{h}) = 0.337 \text{ mSv m}^2 / \text{GBq h}$$

$$\text{GBq} = \text{mSv m}^2 / \Gamma = 10 \cdot 36 / 0.337 = 1068 = 1.1 \text{ TBq}$$

## With 10 cm Fe shielding

Element: Mass:

Co 60  Nuclide Mixtures Selector

Dosimetry and Shielding    Dose rate/Thickness graph    Options

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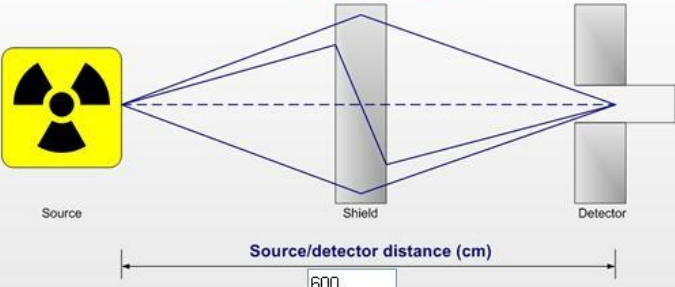
**Source strength**

Activity(Bq)

**Shielding material**

Fe  cm

**Dose rate (μSv/h)**



Source    Shield    Detector

Source/detector distance (cm)

Start    Reset

|  |          |
|--|----------|
| Half-Value Shield Thickness(cm)                            | 4.27E+00 |
| Tenth-Value Shield Thickness(cm)                           | 9.90E+00 |
| Equivalent Dose Rate Constant Γ(mSv·m <sup>2</sup> /GBq·h) | 3.37E-01 |
| Gamma Dose Rate (μSv/h)                                    | 9.98E+02 |
| Effective Build-up factor                                  | 6.45E+00 |
| Effective Number of Mean Free Paths (μ·d)                  | 4.20E+00 |

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## **Result:**

**Dose rate decreased by a factor of  $\sim 10$  with 10 cm Fe**

## **Conclusion:**

**as amount of shielding material is not well known  
only estimate possible**

**1.1 TBq without shielding**

**$\sim 10$  TBq with 10 cm Fe**

**Remark: source had 15.7 TBq**

## Next problem: recovery

### Dose rate in 1 m distance for 15.7 TBq $^{60}\text{Co}$ ?

Element: Mass:

Co 60  Nuclide Mixtures Selector

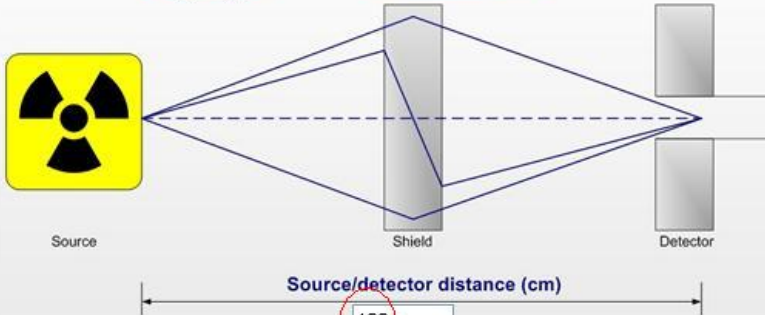
**Dosimetry and Shielding**   Dose rate/Thickness graph   Options

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**Source strength**  
 Activity(Bq) ☒ 1.57E+13

**Shielding material**  
 Air ☐ 100 cm

**Dose rate (μSv/h)**



Source                      Shield                      Detector

Source/detector distance (cm)

|   |          |
|---|----------|
| Half-Value Shield Thickness(cm)               | 2.77E+04 |
| Tenth-Value Shield Thickness(cm)              | 6.50E+04 |
| Equivalent Dose Rate Constant Γ(mSv·m²/GBq/h) | 3.37E-01 |
| Gamma Dose Rate (μSv/h)                       | 5.29E+06 |
| Effective Build-up factor                     | 1.01E+00 |
| Effective Number of Mean Free Paths (μ·d)     | 6.59E-03 |

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5.3 Sv/h



## Recovery 2:

**10 cm Pb shielding**

**What time allowed for 10 mSv?**

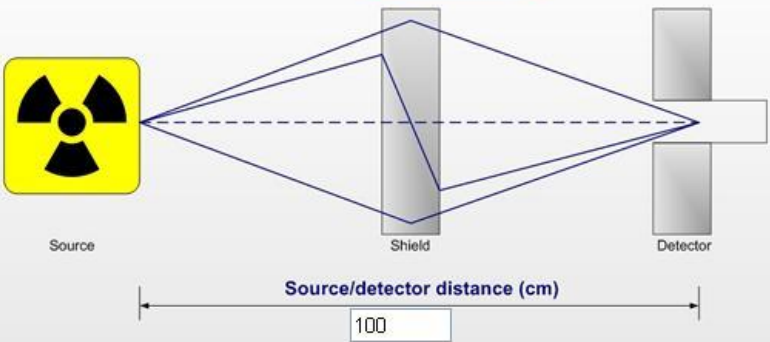
Element: Mass:

Co 60  Nuclide Mixtures Selector

Dose rate/Thickness graph
Options

Source strength
Shielding material
Dose rate (μSv/h)

Activity(Bq) 1.57E+13
Pb 10 cm



Source/detector distance (cm) 100

Start Reset

|  |          |
|--|----------|
| Half-Value Shield Thickness(cm)                            | 2.02E+00 |
| Tenth-Value Shield Thickness(cm)                           | 5.03E+00 |
| Equivalent Dose Rate Constant Γ(mSv·m <sup>2</sup> /GBq/h) | 3.37E-01 |
| Gamma Dose Rate (μSv/h)                                    | 2.93E+04 |
| Effective Build-up factor                                  | 4.30E+00 |
| Effective Number of Mean Free Paths (μ·d)                  | 6.66E+00 |

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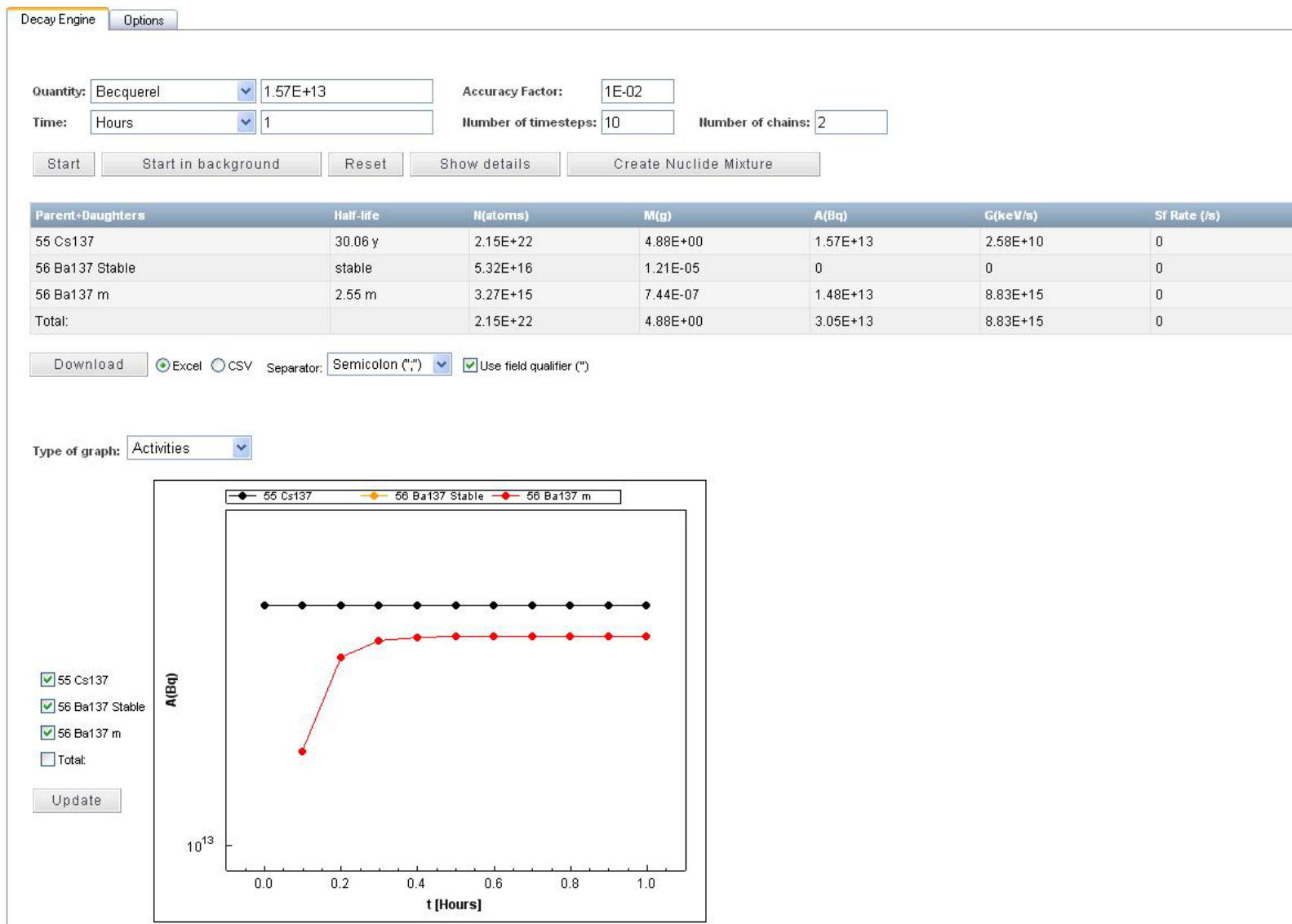
29,3 mSv/h  
 ~ 20 min

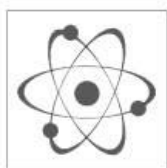
**For comparison:**

**15.7 TBq  $^{137}\text{Cs}$ , 10 cm Pb, 1m distance**

**Dose rate?**







## Nuclide mixtures

### Nuclide mixtures

#### User defined nuclide mixtures

137Cs

☐ Show Details

Name

137Cs

Element

Isotope

Mass

Ac

206

Grams

1

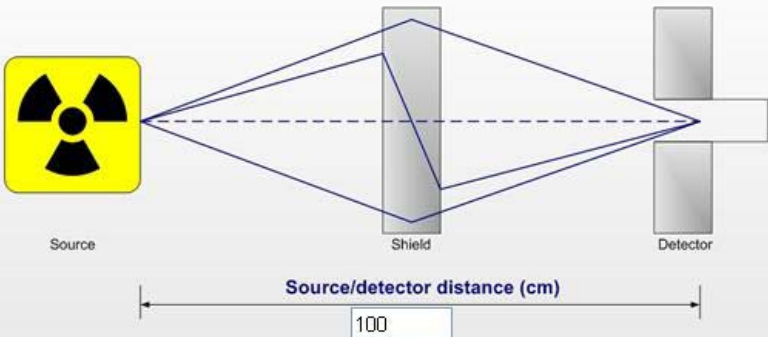
|      | Nuclide    | Activity(Bq) | Mass(g)   |
|------|------------|--------------|-----------|
| Edit | 55 Cs137   | 1.5700E+13   | 4.8815E+0 |
| Edit | 56 Ba137 s | 0.0000E+0    | 1.2105E-5 |
| Edit | 56 Ba137 m | 1.4821E+13   | 7.4430E-7 |
| Edit |            |              |           |
| Edit |            |              |           |
| Edit |            |              |           |
| Edit |            |              |           |
| Edit |            |              |           |

Nuclide Mixtures:  
137Cs

Dosimetry and Shielding   Dose rate/Thickness graph   Options

**Source strength**   **Shielding material**   **Dose rate (μSv/h)**

Activity(Bq) 3.05E+13   Pb 10 cm



Source   Shield   Detector

Source/detector distance (cm)  
100

Start   Reset

|   |          |
|---|----------|
| Half-Value Shield Thickness(cm)               | 9.40E-01 |
| Tenth-Value Shield Thickness(cm)              | 2.43E+00 |
| Equivalent Dose Rate Constant Γ(mSv·m²/GBq/h) | 4.35E-02 |
| Gamma Dose Rate (μSv/h)                       | 1.62E+01 |
| Effective Build-up factor                     | 3.76E+00 |
| Effective Number of Mean Free Paths (μ·d)     | 1.26E+01 |

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